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SIMNET Applications to Peacekeeping Missions

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IDA Central Research Program

PREFACE

This paper was written as part of the Central Research project entitled "Assessment of SIMNET/DIS Applicability to Current SF&RD Tasks." It documents the study team's effort to show the utility of SIMNET/DIS as an analytic tool for addressing task issues. We would like to thank Mr. Richard Carpenter of SED for modifying the Smart-Mine Simulator to simulate sensor fields, thereby enabling us to conduct our trials.

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SUMMARY

A. BACKGROUND

The purpose of this project was to develop an application of distributed simulation for an area of active research in the Strategy, Forces and Resources Division (SF&RD). The ultimate goal is to demonstrate the utility of distributed simulation for addressing issues of current interest. For the purposes of this project, distributed simulation is synonomous with the Simulation Network (SIMNET), or its more current name, Distributed Interactive Simulation (DIS).

After surveying SF&RD activities, the project team focused on peacekeeping missions as defined in the task entitled "Use of Advanced Sensors and Information Processing Systems to Create Safe Areas and Barriers in Support of Peacekeeping and Related Operations," sponsored by the Defense Nuclear Agency. This area was selected because SIMNET/DIS seemed well suited for addressing the utility of advanced sensor technology in helping security or peacekeeping forces maintain "safe areas" and havens by preventing penetrations by hostile individuals or small units.

B. TESTING

The project team conducted a series of 18 trials to determine the applicability of SIMNET/DIS as a tool for analyzing peacekeeping issues such as:

- Comparative utility of different types of sensors
- Sensor deployment strategies
- Deployment strategies of peacekeeping and security teams

These tests were not conducted under tightly controlled conditions, nor were they executed in accordance with a carefully designed test plan. The intent was not to draw inferences but to explore applicability to peacekeeping issues by running excursions under widely varying conditions.

Tests were conducted in the IDA Simulation Center using Modular Semi-Automated Forces, version 1.0 (ModSAF1.0). ModSAF1.0 is an interactive simulation that allows a user to create and deploy forces (individual vehicles, dismounted infantry

squads, or higher echelon units), generate lists of commands, and regulate the effectiveness of units and objects under his control. Three people took part in each test: a response team commander, an infiltrator commander, and a sensor monitor. Each commander had one Silicon Graphics Indigo workstation (SGI) that displayed his forces, the terrain, and any opposing forces that his unit or individual squad members detected. The sensor monitor controlled three workstations: two that were required for the sensor simulation, plus an additional SGI that recorded the trials. Exercises ran in real time.

Games were generally conducted in the vicinity of Sarajevo or Mostar. An exception was the sole trial in which a manned simulator was used (the Fort Benning terrain database was used in this case). Play generally began with the sensor monitor deploying sensor fields across an agreed upon "safe area" boundary, while the infiltrator commander executed orders for either two- or five-man infiltrator teams to begin their penetration. Upon receiving sensor reports, the response team commander deployed either 8- or 16-man response teams to the vicinity of the incursion.

The tests fell into two broad categories: five-man infiltrator tests and two-man infiltrator tests. In the former, 16-man response teams were deployed in either rotary wing aircraft (RWA) or infantry fighting vehicles (M2). Comparisons were made between the two transportation methods in terms of the number of infiltrators captured, the capture rate, penetration depths, and a few other measures of effectiveness (MOEs). In the latter (two-infiltrator trials), eight-man teams were deployed on foot to capture the infiltrators. These tests examined "end game" tactics as a function of sensor delpoyment strategies. The MOEs were expanded to include the number of casualties suffered by the response teams.

The manned simulator trial, while technically a two-infiltrator exercise, differed significantly from the others and is treated here as a special case. The simulator was an M2 Bradley and contained a nonstandard crew of four individuals who constituted the response team. The purpose of the manned test was to explore the feasibility of using the simulator in conjunction with ModSAF in a peacekeeping exercise.

Eighteen tests were conducted. Three were practice, five were two-infiltrator trials, eight were five-infiltrator trials, one was a manned simulator trial, and one resulted in a system failure (and was unrecorded). These are summarized below in Table S-1.

Table S-1. Matrix of Cases

Game	Infiltrators	Team Size	Vehicle
1[a]	5	32	4 M2s
2[a]	5	16	2 RWAs
3[a]	5	16	2 RWAs
4	5	16	4 M2s
5	5	16	2 RWAs
6	5	16	2 RWAs
7	5	16	2 RWAs
8[b]	5	16	2 RWAs
9	5	16	2 RWAs
10	5	16	4 M2s
11	5	16	2 M2s
12	2	8	foot
13	2	8	foot
14	2	8	foot
15	5	16	2 M2s
16	2	8	foot
17	2	8	foot
18[c]	2	4	1 M2

a-practice   b-crash   c-manned

C. TEST RESULTS

Very few trials were conducted. The relative errors of the MOEs collected are unusually large. The intent never was to draw inferences based on outcomes, but to explore the feasibility of SIMNET/DIS as a tool. Nonetheless, statistics were collected and are displayed throughout this report. The various figures and tables demonstrate how SIMNET/DIS might be used by showing what can easily be collected.

Table S-2 shows some mean or median values of the MOEs for the five-infiltrator trials. In the four trials in which response teams were deployed in M2s, 3.5 infiltrators were apprehended, on average. In the trials (also four) in which teams were deployed in RWAs, 3.75 were apprehended (mean). The difference is not significant.

Two different methods of measuring capture rates were used. In the first, the number of infiltrators captured was divided by the length of time from team deployment to the last capture. In the second, time was measured from the moment the teams left their home base ("move out"). Using the former measurement, M2-deployed teams captured infiltrators at a slightly higher rate than RWA deployed teams (5.87 per hour compared with 5.42 per hour). This difference may reflect the fact that helicopters typically deployed their teams farther from the suspected infiltartor location than M2 teams due to RWA vulnerability to ground fire. Rates reverse (4.82 for RWA and 4.27 for M2) when the second method is used—most likely because of the shorter time it takes the RWA to get to its deployment point.

Median distances to which infiltrators were able to penetrate beyond the "safe area" boundary were also recorded. The median appeared the more reasonable statistic (than the mean) in this case because some infiltrators were never caught. An arbitrary (4-km) depth was assigned to these. The median is somewhat less affected by this assignment than the mean. Captures, rates, and depths are summarized for the five-man infiltrator trials in Table S-2.

Table S-2. Summary MOEs

Vehicle	Captures (mean)	Rate1 (mean)	Rate2 (mean)	Depth (median)
M2	3.5	5.9/hr	4.0/hr	3.4 km
RWA	3.8	5.4/hr	4.8/hr	2.2 km

The two-infiltrator cases focused on the impact of sensor type and deployment strategies on the "end game." The central issue was how sensors might be used to make the capture process safer for response teams. These trials were conducted in a narrow corridor in which two infiltrators attempted to circumvent eight foot-deployed team members. Two strategies were examined. In the first, sensors were deployed in three bands, each separated by about half a kilometer, across the expected penetration route. In the second, sensors were deployed throughout the entire area in which encounters were expected to take place. In two of the "band" trials, elementary sensors (reporting only detections and the sensor's own position) were deployed. In the remaining "band" trial and in the two "area" deployment trials, a more sophisticated sensor (reporting target position and velocity) was deployed.

While too few trials were conducted to offer robust conclusions, the outcomes were sufficiently interesting to suggest areas of future study. Specifically, it appeared that the number of captures was not strongly affected by sensor type or deployment method. In almost all cases, both infiltrators were captured. Team losses, however, dropped when smart sensors were "area" deployed. It is possible that the teams derived some benefit from frequent updates about intruders' positions. Also, the velocity data helped differentiate infiltrator from team member when the two were close together, but out of line-of-sight. Table S-3 summarizes the two-man infiltrator tests.

Table S-3. Summary of Two-Infiltrator Trials

Captures	Losses	Deployment
2	2	3 belts
1	2	3 belts
2	3	3 belts
2	2	area
2	1	area

The manned simulator trial was conducted to detemine the utility of the manned simulator as an analysis tool. The simulator was an M2. Its crew in this exercise was a commander, a driver, a gunner, and a message handler. The latter position was added in part becasue there was no direct communications line between the sensor monitor and the crew compartment. Someone had to periodically leave the vehicle and talk directly to the monitor to get position information about the infiltrators. This trial was conducted on the Ft. Benning terrain database because the simulator could not access the Bosnian terrain.

This test suffered from two major difficulties. The first was the impaired communications. The second was the difficulty in keeping an infiltrator in view after he was detected. This was due to the lack of an open hatch through which the surrounding area can be seen. Both infiltrators were apprehended in this exercise. The amount of time required was slightly greater than in the "foot" trials.

D. CONCLUSIONS

It appears that SIMNET/DIS can be used effectively to analyze peacekeeping issues. Insight about trafficability and response times is gained from moving vehicles

across the terrain database. These data can be used to formulate trade-offs about various transportation systems for the response teams. Captures, encounter rates, and susceptibility can be measured by conducting enough tests. Deployment strategies for both the teams and the sensors can be explored. Effects of different sensor technologies can be gauged.

Ultimately, the utility of SIMNET/DIS depends on two notions: the MOEs that can be collected, and the realism of the simulation. The few MOEs reported in this paper were the ones that were easy to record. They were intended to give the reader some flavor for what is available but were by no means exhaustive. One should keep in mind that every position and movement of a SIMNET/DIS entity can be captured. This is potentially a wealth of information for the analyst.

The realism of the simulation is an open topic. One has to remember that SIMNET/DIS can portray the effect of a system but cannot measure a system's capability. Realism is likely to suffer if one attempts the latter. Perhaps its payoff is in illuminating the things that people do when they enter a competitive environment. Their ability to use small bits of correlated information to their advantage and help control the situation as it unfolds is rewarded in SIMNET/DIS.

I. INTRODUCTION

A. BACKGROUND

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The apparent suitability of SIMNET/DIS stemmed from two principal assets: the availability of realistic terrain databases that include areas of the world where peacekeeping missions are likely to occur (e.g., Bosnia), and the availability of a sensor simulation (an adaptation of the IDA Smart-Mine Simulator). Other features were, of course, also important. In particular, the capability to model small dismounted infantry units and the ability to conduct free-play engagements were important to this effort.

The objective of this paper is to report the results of the project team's examination of SIMNET/DIS as a tool for analyzing peacekeeping issues.

B. ISSUES

1. Peacekeeping Issues

The use of demilitarized zones, safe areas, and barriers is likely to become commonplace in future peacekeeping and stabilization operations. With regional and tribal wars becoming more frequent, it is not unreasonable to expect increasing social and

political presssure to increase our involvement in these types of missions in the future. Candidate areas of the world include the former Yugoslavia, Africa, the Middle East, the Indian subcontinent, and the Korean Peninsula. Historically, there have been attempts to use modern technology to monitor intrusions of hostile forces. The most prominent example is, perhaps, the "McNamara Line," a sensor field deployed in Southeast Asia in the 1960s.

With the advent of modern electronics and computer technology, sensor applications in peacekeeping roles hold new promise. Lightweight airborne and hand-held sensors are capable of detecting infiltrators at distances of several kilometers. Seismic and acoustic sensors can identify types of vehicles passing within a few hundred meters. Smart sensors, coupled with a central unit capable of pooling and processing multiple reports may in the near future reduce risks as well as costs and increase efficiency by performing tasks traditionally in the realm of human observers and monitors.

The project focused on the following peacekeeping issues:

- The ability of sensors to detect infiltrators who may be penetrating sanctuaries on foot or in light vehicles.
- The information conveyed by such sensors.
- The deployment strategies of teams in response to sensor reports (detections).
- The cost/effectivenss trade-off of the various means available for transporting response teams.

2. SIMNET/DIS Issues

In order to make a case for applying SIMNET/DIS to a funded task, it was necessary to demonstrate the relevance and utility of distributed simulation. As a practical matter, this entailed addressing four major issues:

1. Whether SIMNET/DIS could model dismounted infantry (DI) in a manner that replicated the actions and movements of infiltrators and response teams. Specifically, it was necessary to determine whether SIMNET/DIS suitably represented the activities associated with an individual or small group attempting to violate a sanctuary boundary, evade guards and patrol units, and then penetrate deeply into hostile territory.
2. Whether a sensor model existed that could be used in conjunction with dismounted infantry and other SIMNET/DIS entities.

3. Whether enough workstations were available to allow an exercise to be run successfully.
4. Whether a terrain database was available for an area of interest to a potential sponsor.

There were two feasible models for dismounted infantry: the Semi-Automated Dismounted Infantry System (SAFDI) and the infantry squad model contained in Modular Semi-Automated Forces, version 1.0 (ModSAF1.0). SAFDI is an infantry simulation developed by the Institute for Simulation and Training at the University of Central Florida. Some of its capabilities include the ability to model fireteams who can move, change posture, detect and engage enemy units, communicate with the operator, and mount or dismount armored personnel carriers. SAFDI requires two workstations: a user interface and a simulation component.

ModSAF1.0 is a more general simulation developed by Loral that allows users to generate vehicles and soldiers at various levels of aggregation (echelons), and give them orders to perform prescribed tasks. ModSAF1.0 requires only one workstation. While SAFDI has a more detailed infantry representation, the broader nature of ModSAF1.0, plus greater familiarity with this model, made ModSAF1.0 the first choice for this application.

To verify the suitability of ModSAF1.0 dismounted infantry as a representation of infiltration units and response teams, the project team conducted drills in which DI units were deployed on various types of terrain, given orders to move to prescribed points, and forced to engage units of the opposing force along the way. These drills also provided practice for players who would ultimately have to control combat units during the actual trials.

The question of a suitable sensor representation was addressed with the Smart-Mine Simulator (SMS). The SMS had been developed as a mechanism for introducing smart-mines (such as wide-area antiarmor mines, and antihelicopter mines) into the SIMNET battlefield. It consists of two workstations acting in unison to simulate aspects of mine warfare. Since SMS emplaces fields of mines, it appeared reasonable to expect that it could be modified to emplace sensor fields capable of detecting DI and ground vehicles. With some effort, this modification was achieved and a workstation capable of emplacing sensor fields became available in April 1994.

Machine availability remained an issue. In order to conduct a trial in which infiltrators penetrate an area and move about concealed from response teams, at least two

workstations are needed (one for each side). Since the SMS also requires two workstations and one additional machine is necessary in order to record exercises, a minimum of five (networked) machines are needed to conduct a trial. As the IDA simulation center generally supported between six and eight workstations at the time, it appeared that sufficient resources existed to conduct a series of trials. (Of course, this assumed that all remained in working order. A subsequent acquisition of six more workstations will alleviate these constraints in the future.)

A terrain database of the area southwest of Sarajevo was selected for this exercise. This appeared to be a region in which peacekeeping operations were likely to be performed in the future. One other database was also used because of its compatibility with one of IDA's manned simulators.

II. TESTING

A. TOOLS AND ENVIRONMENT

1. ModSAF, SGIs, and the Manned Simulator

Tests were conducted using ModSAF1.0. This simulation software suite allows users to create units ranging from DI squads to platoon-sized armor units, control their missions, and regulate their effectiveness. Internal algorithms govern their detection and engagement processes. ModSAF1.0 is executed from host workstations and permits several users to interact with one another over a local area network.

All trials were conducted on Silicon-Graphics Indigo (SGI) workstations in the IDA simulation center. Trials were conducted by three players: one infiltrator commander, one response team commander, and one sensor monitor. The SGIs were nodes on a local area network, allowing information to be passed back and forth among the various workstations. The workstations were configured so that the units (DI and whatever vehicles were being played) belonging to opposing sides would not be visible to one another until an actual line-of-sight detection took place.

One excursion made use of a manned simulator, an M2 Infantry Fighting Vehicle. This simulator was connected to the local area network on which the SGIs running ModSAF and the SMS resided. It contained an nonstandard crew of four individuals (commander, driver, gunner, and a message handler or communications specialist) who attempted to apprehend DI infiltrators created by ModSAF and controlled through a remote SGI workstation.

2. Smart-Mine Simulator

To simulate the effects of ground sensors, the Smart-Mine Simulator (SMS) was converted to model ground sensors. This required deactivating software that controls the mine's munition launch sequence. All other features of the SMS were retained, including its two-workstation mode of operation. One workstation, the graphical user interface, allows the user to specify sensor locations, densities, and types. This interface displays a

terrain map of the area of interest and enables the user to specify sensor field locations by drawing polygons on the map surface. Sensor densities and types are specified through dialog boxes and menus. All transactions are controlled by "mouse clicks" and keyboard strokes.

The second workstation, known as the host workstation, controls network communications and houses all algorithms affecting SMS performance and behavior. Messages reflecting SMS status are displayed on its monitor. These include sensor detection reports, in the form of text messages, as well as summary statistics relating field sizes and types of sensors deployed.

3. Play of the Game

Before play began, each commander would construct his or her forces by first activating ModSAF1.0, then selecting the types of forces to be deployed from the appropriate menus. He would then position his forces according to the agreed upon ground rules for the particular trial to be conducted. In the case of the infiltrator commander, incursion routes were selected and orders for infiltrating DI to follow these routes were issued. The response team commander usually would not issue orders until sensor detections revealed positions of the opposing force. There were some exceptions to this in those cases where forces were prepositioned in forward areas.

The sensor monitor had the responsibility for emplacing sensor fields and then reporting detections to the response team commander. Sensor fields were emplaced using the SMS by drawing field boundaries on a digitized terrain map with an electronic mouse. The sensor monitor also had responsibility for operating the recording software, known as the Table_Logger. As this only required starting and stopping the software, operating the Table_Logger was not manually intensive and generally did not interfere with other functions.

Depending on the scenario, the infiltrator would create two-man or five-man DI squads. With the exception of the manned simulator trial, infiltrators would attempt to traverse 4 km of terrain to reach a "goal line"; presumably from this line, they would be in small arms or mortar range of a lucrative target. Infiltrators were restricted to a 2-km-wide corridor in the two-man scenarios and a 5-km corridor in the five-man trials. In the manned simulator case, the corridor was also 2 km wide, but only 3 km long. The scenarios are summarized in Table II-1.

Sensor belts were placed across the corridors of interest in the five-man trials. Belts were placed about 1 km from the infiltrators' initial position, or about 3 km from the goal. Two excursions did not make use of sensors: one deployed eight DI sentinels, the other used no detection systems at all. In the two-man cases, sensors were either emplaced in belts across the corridor or distributed throughout a subregion in which engagements were expected to take place.

Response teams generally consisted of 8- or 16-man DI units. The larger teams were used in the five-man infiltrator games and were positioned approximately 2 to 3 km to the rear of the infiltrators' goal. From their base positions, they were transported either by ground vehicle or rotary wing aircraft to a deployment point from which they would disembark and attempt to apprehend the infiltrators. In two-man infiltrator scenarios, other than the manned simulator case, an eight-man response team was prepositioned 3 km in front of the goal. The team had no vehicular support in these cases. In the manned case, the vehicle crew was the response team; it began the game on the goal line.

Each trial was run in real time. Action took place at rates driven by the amount of time required for DI to walk 2 or 3 km. Typically this meant that games lasted between 45 minutes and 1.5 hours. Some of the two-infiltrator games were completed in less than 20 minutes.

Table II-1. Corridor Dimensions, Number of Sensors, Team Position and Size

Scenario	Corridor Width (km)	Corridor Length (km)	Team Size	Team Offset
5 man	5	4	16 DI	1.5-3 km rear
2 man	2	4	8 DI	3 km forward
manned simulator	2	3	4-man crew	at goal

B. TEST DESIGN

1. Matrix of cases

This exercise was intended to demonstrate the applicability of SIMNET as a tool for studying issues related to the use of sensors for peacekeeping missions. It was not conducted with an experimental design that would allow policy makers to draw inferences about these issues. In particular, too few cases were run under controlled conditions.

Instead, interest was focused on running different excursions. Nonetheless, outcomes were recorded and certain scenarios were repeated in order to explore small sample trends, if any.

As mentioned above, the exercise was divided into two major groups: five-man infiltrator trials and two-man infiltrator trials. The former were designed to compare and contrast the effects of the two principal means of transporting response teams: helicopters and ground vehicles. The latter trials were designed to examine the utility of sensors in "end game" operations in which response teams and infiltrators are separated by short distances but may not be in line-of-sight of one another.

The trials are summarized in Table II-2. Each is identified by number, terrain region where the exercise took place, number of infiltrators, response team size, response team transportation method, and sensor type. These items (parameters) will be discussed fully in the later sections. Table II-2 will serve as a reference for the trial discussions that will follow.

Table II-2. Matrix of Cases

Game	Location	Infiltrators	Team size	Vehicle	Sensors
1[a]	Mostar	5	32	4 M2s	D
2[a]	Mostar	5	16	2 RWAs	D
3[a]	Mostar	5	16	2 RWAs	D
4	Mostar	5	16	4 M2s	D
5	Mostar	5	16	2 RWAs	D
6	Mostar	5	16	2 RWAs	sentinel
7	Konjic	5	16	2 RWAs	D
8[b]	Mostar	5	16	2 RWAs	D
9	Mostar	5	16	2 RWAs	D
10	Mostar	5	16	4 M2s	D
11	Sarajevo	5	16	2 M2s	D
12	Sarajevo	2	8	foot	D
13	Sarajevo	2	8	foot	D
14	Sarajevo	2	8	foot	D
15	Sarajevo	5	16	2 M2s	none
16	Sarajevo	2	8	foot	PV
17	Sarajevo	2	8	foot	PV
18[c]	Benning	N/A	4	1 M2	PV

a-practice b-crash c-manned N/A-not applicable

Table II-2 includes four unrecorded trials (that is, unrecorded by the Table_Logger). One entailed a system malfunction in which infiltrators and response teams could not detect one another because their respective workstations were not communicating. The others were practice games conducted before the corresponding recorded exercises.

2. Location

With the exception of two excursions, test trials were conducted near the Bosnian cities of Sarajevo or Mostar. One exception was an exercise conducted in the vicinity of Lake Jablanicko Jezero, near the town of Konjic approximately 30 km north of Mostar. The other was the manned excursion which took place on Fort Benning terrain because Bosnian databases were not accessible to the simulator.

Those trials taking place near Sarajevo or Mostar were conducted in corridors approximately 3 to 7 km west of the cities. The excursion in the lake region near Konjic took place about the same distance west of Lake Jezero. The excursion in Fort Benning took place immediately east of the military installation.

3. Transport Systems

In all five-man trials, response teams were transported by either four M2 infantry fighting vehicles or two rotary wing aircraft (RWA). In the cases involving M2s, teams were transported in four-man squads. In the RWA cases, teams were broken into two eight-man squads. In two-infiltrator cases, response teams moved on foot or in the manned simulator. The transport details are summarized in Tables II-3.

Table II-3. Terrain and Team Deployment Method

	Team Deployment Method		
Type of Trial	RWA	M2	Foot
5 Infiltrators			
Sarajevo	0	2	0
Mostar	3	2	0
Konjic	1	0	0
Subtotal	4	4	0
2 Infiltrators			
Sarajevo	0	0	5
Benning	0	1(manned)	0
Subtotal	0	1	5
Unrecorded	3	1	0
Total	7	6	5

4. Sensors

Two different types of sensors were deployed: Detection *D* and position velocity *PV*. The *D* sensors reported only detections and the position of the sensor making the detection. The *PV* sensors reported the position of the detected infiltrator and its velocity. *D* sensors were used in six of the five-man infiltrator trials and in two of the two-man trials. *PV* sensors were used in four trials, including the manned exercise.

Sensors were emplaced with approximately 144 meters between nearest neighbors in all but the manned simulator case. In the manned case, spacing was 200 meters. Typically 60 to 85 *D* sensors were deployed in the five-man infiltrator cases and between 35 and 81 *D* or *PV* sensors in the two-man infiltrator cases. Approximately 155 *PV* sensors were deployed in the manned exercise.

Two trials were conducted without sensors. In the first of these, eight sentinels were deployed in a belt across the expected infiltration routes. A full response team was deployed in addition to the sentinels. In the other trial, no sensors or sentinels were used. Response teams were deployed at the commencement of the game to the "frontier" which infiltrators were expected to cross. The excursion with sentinels was conducted near Mostar, while the other took place outside Sarajevo. Table II-4 summarizes the sensor deployment.

Table II-4. Sensor Type and Team Deployment Method

	Team Deployment Method		
Type of Trial	RWA	M2	Foot
5 Infiltrators			
PV Sensors	0	0	0
D Sensors	3	3	0
No Sensors	1 (sentinels)	1	0
Subtotal	4	4	0
2 Infiltrators			
PV Sensors	0	1 (manned)	3
D Sensors	0	0	2
No Sensors	0	0	0
Subtotal	0	1	5
Total	4	5	5

C. TEST RESULTS AND ANALYSIS

1. Overview

This section presents a series of graphs and tables to demonstrate the types of statistics available from SIMNET exercises. The graphs and tables are a collection of "snap shots" of outcomes of various trials conducted on the Bosnian and Fort Benning

terrain databases. Typically, they portray results related to performance by response teams as a function of their transportation mechanism (e.g., RWA or M2) or sensor deployment strategy. Again, as stated at the beginning of the previous section, they are not outcomes of a carefully constructed experimental design. Ambient conditions were not held constant from trial to trial. Instead, they are tabulations of results from a small number of trials in which various excursions were included for the express purpose of demonstrating applicability of SIMNET/DIS to the analysis of peacekeeping missions. Nonetheless, some statistical analysis is included where it seems appropriate to the discussion.

2. Five-Man Infiltrator Exercises

a. Captures

The principal measure of effectiveness (MOE) in these exercises is the number of infiltrators captured by the response teams. This MOE gives, arguably, the strongest indication of the efficiency of the response teams, their strategy for dealing with intrusions, and the capability of their commander. As samples are small, cases are grouped together across different terrain regions (Sarajevo and Mostar) and sensor deployment strategies. In particular, results from trials without sensors are displayed along with those in which sensors or sentinels are utilized. Figure II-1 shows the numbers of captures by RWA- and M2-deployed response teams. Both graphs in the figure refer to five-man infiltrator trials.

The average number of infiltrators apprehended in games in which dismounted infantry were deployed in M2s was 3.5 and 3.75 in games where infantry were deployed in RWA. As sample sizes were so small (and relative errors large), the difference between the number of captures is not significant.

The number of captures in the case of M2-deployed teams does not appear to be greatly affected by the change in terrain (games 4 and 10 take place near Mostar, while 11 and 15 take place near Sarajevo) or by the absence of sensors (game 15). However, captures for RWA-deployed teams are lowest in the Sentinel and Konjic scenarios (games 6 and 7), suggesting a dependence on sensors and terrain.

The rate at which infiltrators are captured is another interesting MOE. This measure has an impact on such issues as the cost candidate transport systems, the number of vehicles that should be deployed, and the size of response teams. (Of course, the same could be said about the previous MOE, as well.) Two capture rates are shown in Figure II-2. The first is the number of intruders captured divided by the length of time between

the first deployment of dismounted infantry and the last capture. The second is the number of captures divided by the length of time between dispatching the first vehicle ("moving out") and the last capture. The mean values represent the total number captured in all games divided by the sum of the corresponding time intervals for all games.

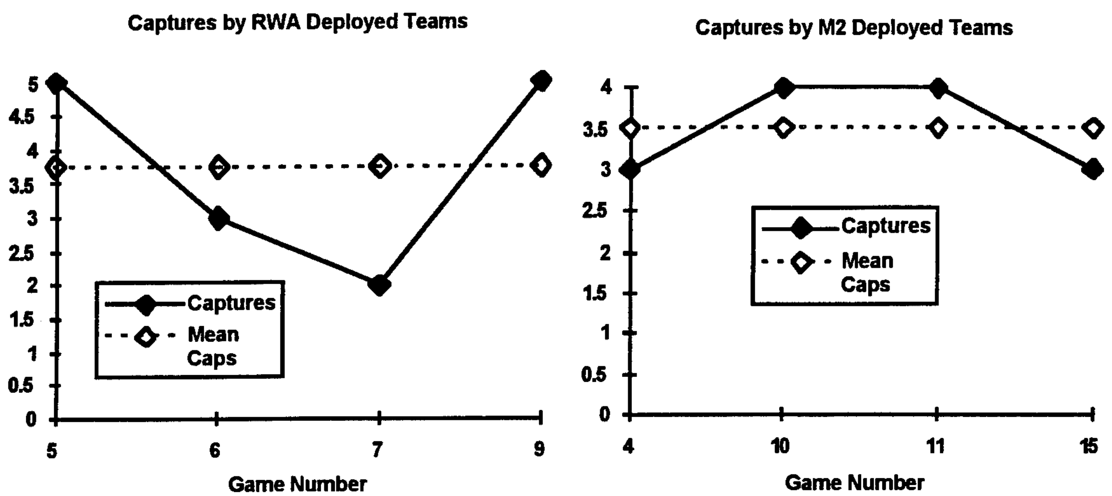
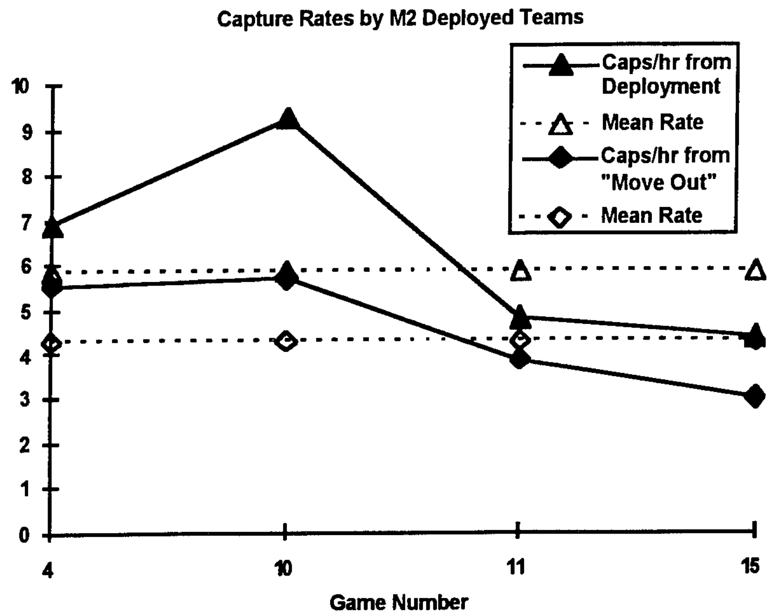


Figure II-1. Captures Vs. Transport System

When measuring from the first DI deployment, the average capture rate for RWA-deployed infantry is 5.42 intruders per hour and the rate for M2 deployed infantry is 5.87 per hour. A possible explanation of the difference is the fact that M2s could safely deploy infantry closer to the expected location of the intruder than was possible for the RWA. When RWA approached intruders too closely, they became vulnerable to machine gun fire, whereas the M2s were relatively immune.

When measuring from the time the first vehicle is dispatched, the mean capture rates for RWA-deployed teams and M2-deployed teams are 4.82 and 4.27 infiltrators per hour, respectively. This rate reversal is apparently due to the shorter time required for a helicopter to reach its initial "drop zone." These explanations should not be take too seriously, however, as the differences in means is insignificant in all cases, regardless of which type of measurement is used.

Both RWA-and M2-deployed teams appear affected by differences in terrain and the absence of sensors. The impact is more dramatic in the RWA case.



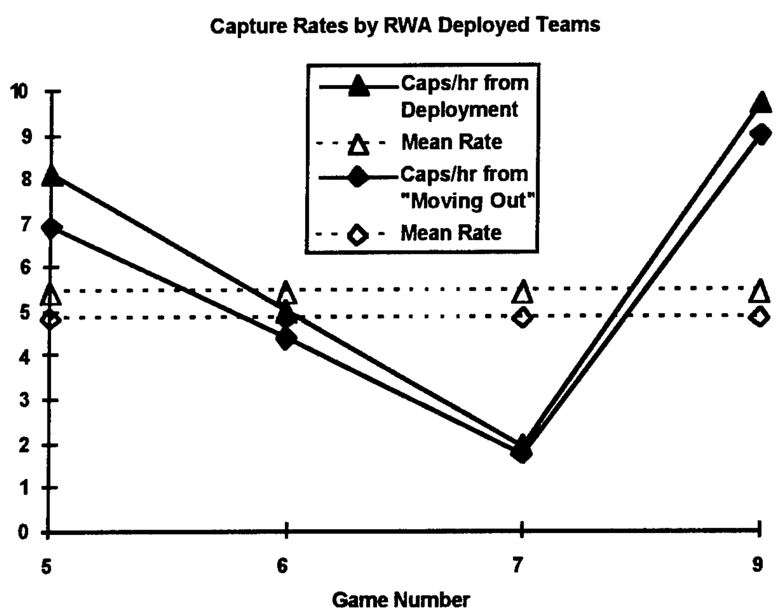


Figure II-2. Number of Captures Vs. Team Deployment Method

b. First Encounters

Another statistic that may lend insight into the relative merits of air and ground deployment systems is the time to the first encounter between response teams and infiltrators. An encounter in this case means an exchange of gun fire between opponents.

This statistic, or MOE, provides information about the ability of response teams to react to an incursion after detection has occurred (or in the no-sensor case, after some indication has been received that infiltration has taken place). As in the case of capture rates, time intervals are measured both from the time vehicles "move out" and from the time DI are deployed. These times are displayed in Figure II-3, below.

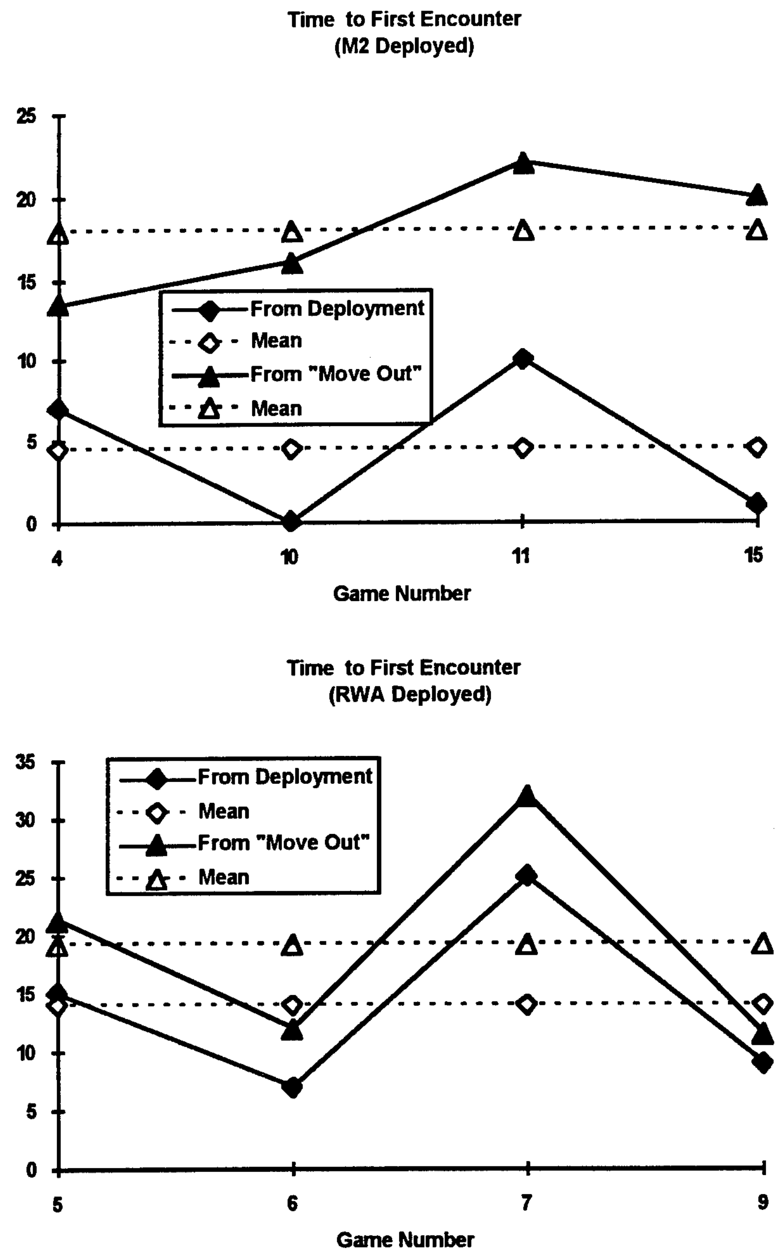


Figure II-3. Time to First Encounter

By both methods of measuring, the time to first encounter is less for the M2-deployed response teams than for the RWA-deployed teams. This is somewhat strange because the RWA move at a much higher rate than the M2s (approximately 72 km per hour compared with 29 km per hour on level terrain). However, as suggested in the discussion of capture rates, other factors are brought to bear. One is the fact that only two RWA are available, as opposed to four M2s. This may give the ground vehicles some advantage by enabling them to deploy forces along the frontier simultaneously, perhaps increasing chances of an early encounter. But more importantly, M2s can approach the infiltrators positions at close quarters with relative impunity. Helicopters, on the other hand, can be easily shot down by DI when they hover within range of the latter's weapon systems. This forces the RWA to deposit DI far from the infiltrator's expected positions. This is quantified somewhat by the next series of graphics. Therefore, RWA-deployed DI must travel further on foot to engage infiltrators than their M2 counterparts.

Figure II-4 shows the distance between the nearest infiltrator and the first set of deployed DI, again as a function of transport system. The average separation is approximately 0.8 km greater for RWA than M2s. Also, as shown in Figure II-3, the average difference in time from deployment to first encounter is about 10 minutes. This corresponds to a closing speed of about 5 km per hour, which is reasonable for two DI squads approaching one another.

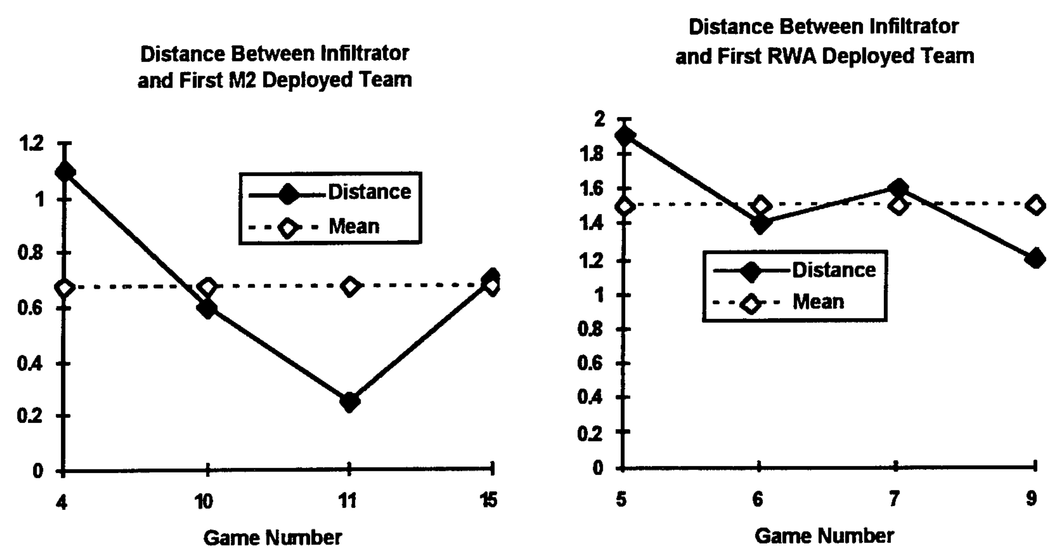


Figure II-4. Distance Between Infiltrator and Response Team at Deployment Point

In terms of two-tailed tests using the t-statistic, the difference between mean times to first encounter is significant at the 10% level when measured from time of DI deployment; it is not significant when measured from vehicle "move out." However, the difference in mean distance between closest infiltrator and response team vehicles at the point of first DI deployment is significant below the 1% level. Losing helicopters to ground fire in practice tests apparently made a very strong impression on the response team commander.

c. Intrusion Depth

Having observed that the number of captures, the rate of capture, and the amount of time required to establish the first contact are approximately the same for both systems of interest (RWA and M2), one would expect that the distance infiltrators cover prior to capture is also about the same. Curiously, it is not. Figures II-5 displays median penetration distances (measured from the starting line established at the beginning of each trial) at which infiltrators were captured for M2- and RWA-deployed teams. The dotted lines in each graph represent the median depth for all four trials taken together in each group (3.4 km for M2s and 2.2 km for RWAs).

A possible explanation of this anomaly is the fact that, by deploying so close to the infiltrators, the M2 transported DI allow the infiltrators to pass through their lines. This forces the response teams to pursue from the west, resulting in deeper penetration distances than would be the case if the teams remained between the infiltrators and the goal.

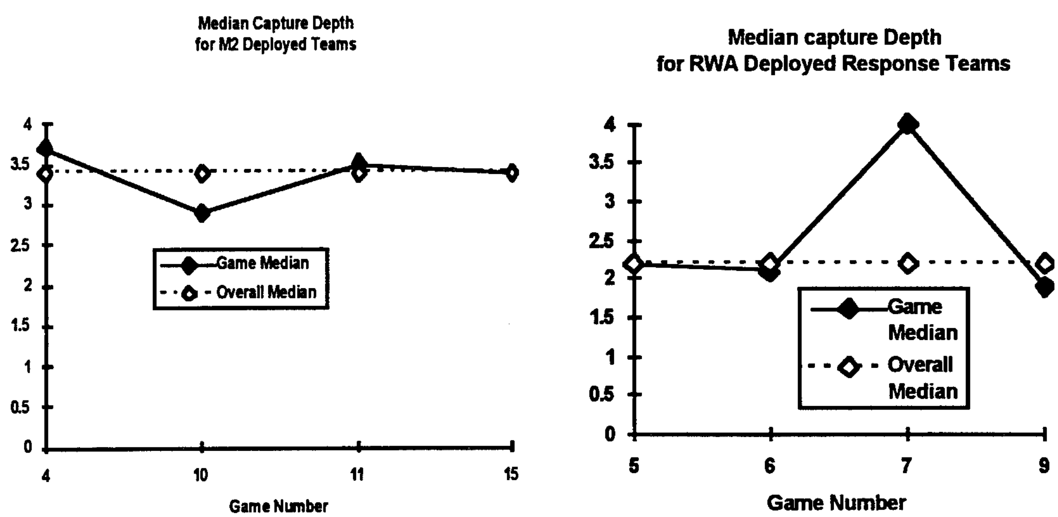


Figure II-5. Median Penetration Depth

The median seems to be a more appropriate statistic than the mean in this case, because the depth to which an infiltrator who is not caught can penetrate is somewhat arbitrary. It more or less depends on when the game is stopped. The median is somewhat less affected by this than the mean.

By bootstrapping the sample depths from each trial, it was possible to construct confidence intervals for the difference in medians. From these it was determined that the difference in medians is significant below the 5% level. Over 1000 bootstrap samples were used in this test.

3. Two-Man Infiltrator Exercises

a. Captures

The two-man infiltrator trials were conducted to explore the impact of sensors on "end-game" conditions. Specifically, they were intended to be used to gain insight into how sensors help response teams safely find infiltrators who are at close range. The notion of safety is emphasized here for the following reason. Since action is taking place at very close quarters, it was virtually assured that opposing units would eventually come into contact. Since ModSAF is really a combat model, the outcome of these encounters was often determined by a fire-fight. Thus, it became something of a point of interest to determine whether knowledge of the opponents presence would give the response teams an advantage in what amounted to small unit engagements.

As described in Section 4, the narrow corridors in which these trials took place were seeded with sensors in various ways. In the earlier tests, narrow bands of *D* sensors were emplaced across the front, middle, and rear of the corridor. In later tests, *PV* sensors were distributed throughout the entire corridor. The following sections summarize how these variations impact such factors as the number of captures, capture rates, average penetration depths, and the number of response team losses.

Table II-5 summarizes the two-man infiltrator cases. Number of sensors, density, team size, captures and losses are tabulated.

Table II-5. Summary of Two-Man Infiltrator Cases

Game	Sensor	Number	Deployment
12	D	43	3 bands
13	D	37	3 bands
14	PV*	53	3 bands
16	PV	81	area
17	PV	81	area
18	PV	155	area

* Trial 14 inadvertently contained some *D* sensors; however, reports were taken from the 53 deployed *PV* sensors, only.

Sensor deployment in Table II-5 refers to the geometric pattern in which sensors were distributed on the ground. In trials 12, 13, and 14, they were distributed in three bands across the infiltrators' paths. In trials 16 and 17 they were distributed throughout a 2-km^2 area in which action was expected to take place. The manned simulator excursion, trial 18, was something of a hybrid in which sensors were distributed over wide expanses of territory; but, because the terrain patch differed and was larger than the other cases, certain portions were left uncovered.

Since the manned excursion differed in so many ways from the other two-man trials, it will be discussed separately at the end of this section. The present discussion refers only to trials 12, 13, 14, 16, and 17.

As described in Section II. B.1, all action took place west of Sarajevo in a narrow corridor about 2 kilometers wide and 2 (4) km long. Eight-man response teams were pre-positioned 1 km east of the infiltrators' starting locations. The response teams were divided into two groups of four. Their objective was to capture the infiltrators, while the objective of the infiltrators was to cross a goal line 4 km east of their initial position.

Since there are so few cases, there is little reason to show separate graphs and tables for, say, PV sensors and D sensors, or belt deployment and area deployment. Instead, categories are combined for display purposes; the reader should have no trouble delineating cases by referring to Table II-5.

Figure II-6 shows that infiltrators were almost always captured. Very little disparity exists among the excursions for this particular MOE. Some variation in the number of response team losses to hostile fire from infiltrators is apparent, however.

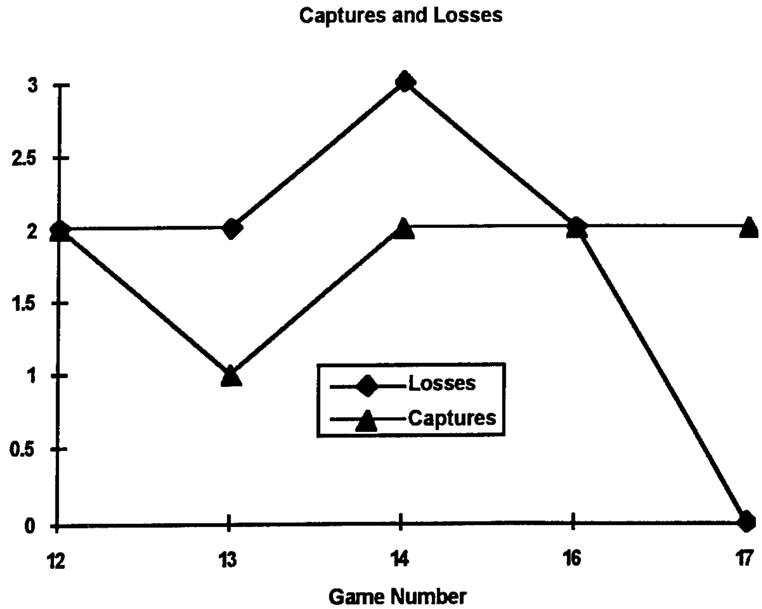


Figure II-6. Captures and Losses in Two-Man Trials

There may be some benefit when *PV* sensors are deployed over an area (trials 16 and 17), or we may be observing an effect due to learning. In any case, it suggests a topic for further investigation.

When PV sensors were deployed in this manner, information about the infiltrators arrived at a rapid rate and enabled the response teams to locate their quarry quickly (as shown in Figure II-7, below). However, it was difficult to prepare the response teams for encounters in a way that would enable them to subdue the infiltrator before a fire-fight occurred. As a result, casualty rates were somewhat uncontrollable.

There was also very little variation in the depth to which infiltrators were able to penetrate. With the exception of trial 13, in which one infiltrator was not apprehended, all were captured between 0.4 and 1.0 km into the corridor. Figure II-7 shows the penetration depths of the captured infiltrators and the median depth of all infiltrators for all two-man trials.

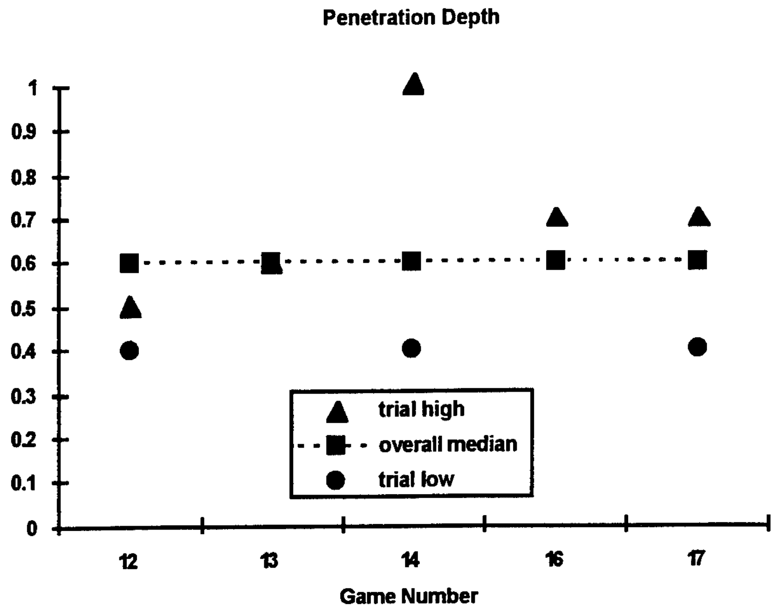


Figure II-7. Infiltration Depth in Two-Man Trials

While the number of captures appears to be relatively constant, some variation exists among the excursions when one considers the rate at which captures take place. Figure II-8 shows the number of captures per trial divided by the time length between "moving out" (typically, the time of the first sensor report) and the last capture. There appears to be an upward trend when *PV* sensors are deployed in area coverage (trials 16 and 17). Capture rates are fairly constant when sensors are deployed in belts, regardless of type of sensor.

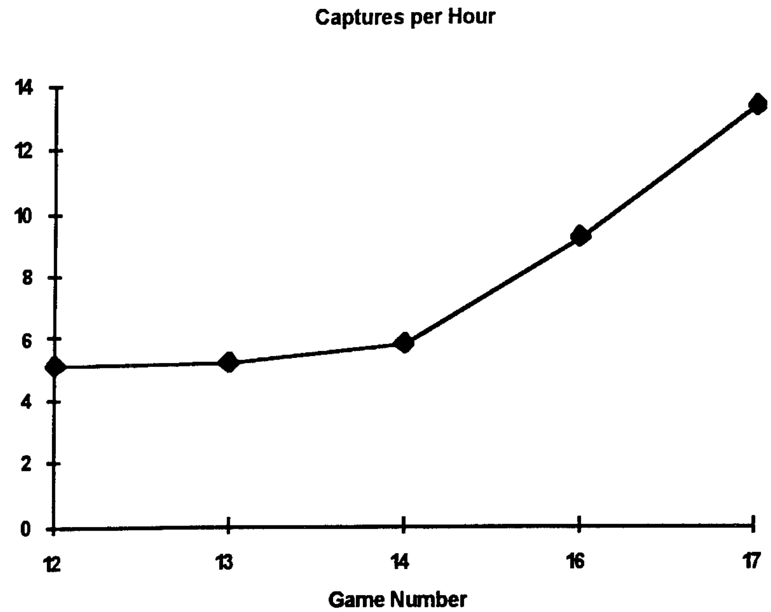


Figure II-8. Rate of Capture in Two-Man Trials

b. Manned Simulator Excursion

The purpose of the manned excursion was to investigate the utility of the manned M2 simulator as a tool for peacekeeping analyses. Since all other exercises were conducted solely using ModSAF1.0, it was of interest to increase the level of human involvement in the testing (and, perhaps, contrast the results). The Bosnian terrain database was not available on the M2 simulator (each host in SIMNET/DIS must carry a copy of the terrain database on which the exercise is being played). Instead, the area encompassing Ft.Benning, Georgia, was used for the trial.

This was a two-man game. Action was restricted to a corridor 3 km long and 2 km wide. The objective was a central portion of the military complex. The only SIMNET players were the M2 and the two infiltrators. No other vehicles or DI were used. In particular, the response team was the M2 crew (commander, gunner, driver, and, in this case, message coordinator). Approximately 155 *PV* sensors were emplaced over various subregions of the corridor in a manner somewhat similar to games 16 and 17. The sensor monitor relayed detections to the message coordinator aboard the M2 from a remote location.

Both infiltrators were killed. One was killed 20 minutes into the game approximately 800 meters from the goal, while the second was killed 30 minutes into the game only 60 meters from the goal. Thus the capture rate, about four per hour, is slightly less than the minimum of the unmanned two-infiltrator trials. One infiltrator carried an anti-tank gun and attempted to engage the M2. Sensor detections began almost immediately; hence, "move out" coincided with the beginning of the trial.

While this was an interesting exercise, there were some drawbacks to the test. First and foremost, there was no direct communication line from the sensor monitor to the M2. Under normal circumstances, a CB-radio is available for such a link. Without a direct way of speaking to one another, the sensor monitor directed the M2 crew towards the infiltrator either by talking directly (in person) to the message handler, or by dropping ModSAF1.0 artillery rounds near the M2 in the direction of the infiltrator.

A second drawback was the difficulty of keeping a detected DI in view of the M2 crew. This apparently was due to the fact that the simulator has no open hatch through which the M2 commander can see the surrounding countryside. Instead, the commander and crew are restricted to small vision blocks from which to view the outside world. Small objects, such as DI, are difficult to see at moderate distances.

3. Qualitative Results and Observations

In this type of testing, where human interaction is combined with a sophisticated computer model that uses many algorithms transparent to the user, one encounters behavior and outcomes that are both unexpected and edifying. ModSAF1.0 is no exception. Typically, these manifest themselves in the way in which players make use of bits and pieces of correlated information supplied by the game.

For example, in the case of helicopter-deployed teams, it is quite possible that infiltrators made use of vehicle movements to glean more up-to-date information about the position of teams than the teams had about the infiltrators. This may have been due to the fact that the helicopters are easy to detect from the ground: they fly high and are easily spotted by dismounted infantry. In contrast, response teams were dependent on sensors to provide position information about the infiltrators. This information degrades over time. With almost 20 minutes elapsing between sensor detection (approximately the same time as "moving out") and the first encounter (see Figure II-3), it was likely that infiltrators had the information advantage.

One such instance was related by the infiltrator commander. In an early trial, his DI detected an RWA departing an area just ahead of their position. The commander assumed this meant response teams had been deployed in his path. He therefore gave orders to his infiltrators to change course in an attempt to evade the teams.

Another information-related issue was the sensor workstation itself. As the data were displayed in text format, it was quite likely that some detections were missed by the sensor monitor. However, since detections were reported on an ongoing basis, it is likely that messages relating to a particular infiltrator were ultimately recognized. Nonetheless, the issue of message recognition is a real one. If, instead of text messages, a graphical display indicated on a map the position where a detection had taken place, few messages would go unnoticed.

Continuing this thought, in the trials in which sensors were deployed, few infiltrators ever went undetected. This is probably due to the fact that infiltrators "came over the border" essentially simultaneously. So, once teams were deployed (because some infiltrators had been detected by sensors) and began spreading out over the country-side, encounters with nearby DI became likely. There were some exceptions in which infiltrators slipped past response teams and were never detected through the entire trial.

This concludes the discussion of the test results. The next section provides some suggestions regarding future DIS-based investigations of sensor and force deployment strategies based upon the outcomes of these trials.

III. CONCLUSIONS AND RECOMMENDATIONS

A. DISCUSSION OF THE MOEs

1. Five-Man Infiltrator Trials

These tests were not conducted under strictly controlled conditions. Few samples were collected. As such, there is little that can be directly inferred from these tests about peacekeeping missions. These tests are important, however, because they point out how SIMNET/DIS can be used as an analytic tool for investigating relevant issues. In other words, these exercises have demonstrated how SIMNET/DIS can be used to test deployment strategies, compare transportation systems, gain insight into the relative merits of different types of sensors, and develop effective force structures and tables of equipment.

It seems appropriate, nonetheless, to comment on the data that were collected. In the five-man infiltrator exercises, the central issue addressed was the relative worth of M2s versus RWA as transportation systems. It appears that little is gained in terms of total captures or mean capture rates by choosing two RWAs over four M2s. Also, the amount of time elapsing between initial sensor reports and the first encounter between response teams and infiltrators is not significantly different for the two systems. If a cost analysis were performed, one would have to assume that the relative costs of the two systems would dictate that M2s are the more efficient system.

Such a conclusion might be premature, however, for two reasons. One reason is the depth to which infiltrators penetrate when confronted by RWA- or M2-deployed teams. The 1-km extension in median depth against M2-deployed teams was one of the few significant statistics in the exercise. If one were able to quantify the value of preventing infiltrators from going this extra distance, relative merits of the two systems might change.

The second reason for skepticism is the ability of M2s to travel off-road. Much of the action took place in what appeared to be heavily wooded terrain. It is unclear that the M2s could have moved with as much facility as they did in many of these trials.

2. Two-Man Infiltrator Trials

The central issue in the two-man infiltrator trials was the impact of sensor types and deployment strategies on the "end-game," or capture process. Two schemes were used: band deployment and area deployment. In these trials the latter were always position-velocity *PV* sensors and the former were always detection *D* sensors. While little difference arose in the numbers of infiltrators captured, distributing *PV* sensors over a wide area enhanced the rate at which captures took place. This was due, in part, to the fact that the velocity report made it easy to discriminate between infiltrator and response team when the two were in close proximity to one another. This increased certainty (about who is being detected) may have some benefit in reducing the number of team casualties. While little difference was apparent in penetration depth, there did appear to be a marked increase in capture rate when *PV* sensors were deployed.

B. IS SIMNET/DIS AN APPROPRIATE TOOL?

The basic question addressed in this paper (albeit indirectly) is whether SIMNET/DIS is an appropriate tool for analyzing peacekeeping issues. The answer depends, in part, on the relevance of MOEs available from SIMNET/DIS, the insights gained from conducting exercises, and the credibility of ModSAF as a model of infiltration and response team operations. Referring to the relevance of the MOEs, one might argue that those analyzed in this paper were the convenient and most obvious ones. They were by no means exhaustive. Instead, they were easily collected without tremendous amounts of data processing and were offered as examples of the type of analyses that are possible. Keeping in mind that the Table_Logger collects all protocol data packets, the analytic opportunities for investigating other physical or functional aspects of peacekeeping missions are fairly broad.

Some analytic possibilites include terrain analyses, such as the trafficability of off-road areas or intervisibility between points where interceptions are likely to take place. These analyses would be useful to mission planners and might be vital to the development of tactics and force structures. More subjective measures include the ability to track targets and correlate sensor detections (SIMNET/DIS protocol data units provide ground truth—complete with position, velocity, and identification number—for all players in an exercise. Data from tracking and correlation algorithms could be compared against these.)

Deployment issues offer another opportunity. For example, in tests using M2s to transport DI, it became clear that it was efficient to deploy DI in squads of two, rather than four. This apparently allowed the DI to spread out more evenly over greater portions of the frontier and therefore increased the chances of an encounter.

Another deployment issue involved the placement of helicopters in the field. When helicopters came within gun range of infiltrators, they were often shot down. This occurred several times in practice sessions and once in a recorded game as the helicopter hovered before or immediately after deploying troops. These downings forced the response team commander to modify his deployment strategy. As mentioned in Section II.C.2, rather than bring his forces up close to the expected position of the infiltator, the Commander deployed DI farther back than initially desired (and farther from the infiltrators than in the M2 trials).

In the case of M2-deployed teams, vulnerability of the vehicle was not the major issue. Instead, the principal concerns were vulnerability of the DI teams deployed too close to the infiltrators and the ability of infiltrators to get between the teams and the goal.

Sensor functionality and deployment issues can be explored. Strategies in which belts are laid at various distances from the frontier can be investigated. In the five-man trials, sensors were typically deployed along the corridor boundary: few were ever deployed in the interior. The benefit of interior deployment could be explored as a function of the team transportation system. Arguably, the distance between belts should reflect the expected amount of time required by the team to respond to the first detections. Also, the benefits of area deployment versus belt deployment might be an area of research. Other strategies, such as deploying sensors along roads instead of along borders warrant investigation. As SIMNET/DIS terrain databases have elaborate road networks, this falls easily within its capabilities.

SIMNET/DIS can be used for testing sensors with different capabilities. In particular, a comparison of the performance of, say, many "detection only" sensors versus few "position-velocity" sensors might provide the basis for a cost-benefit analysis of candidate sensor systems. Modifications to the SMS so that detections are indicated graphically with various attributes (for example, the velocity vector of the target) would facilitate the process.

Finally, because of its large component of human intervention, SIMNET/DIS is unusually well suited for evaluating the ability of those conducting peacekeeping missions to adapt to changing situations. As helicopters crash, or infiltrators disappear, teams must be redeployed and tactics must change. This evolution of strategies can be captured, examined, and evaluated with standard tools. Insights gained from these procedures often are of use for constructing other models, for example PC based software, that are amenable to statistical and sensitivity analyses.

To be balanced and fair, it is necessary to also point out some apparent deficiencies or incompatibilities. For one, ModSAF is a combat model. Authentic "captures" are difficult to model because firefights are the usual encounter. Algorithms are difficult to modify, so not much control can be exerted over the way in which interactions take place. In particular, the manner in which response teams searched for infiltrators could not be controlled. There is little or no ability to focus a team search for an infiltrator other than to point the members in the right direction. Also, DI cannot be detected from helicopters (a problem that will be corrected in newer versions of ModSAF).

On balance, however, there appears to be enough evidence to conclude that distributed simulation, especially its manifestation in SIMNET/DIS, can be a useful tool for gaining insight into issues affecting peacekeeping missions. As new versions of ModSAF are developed and as the intricacies of the software are better understood, it is likely that SIMNET/DIS will become an even stronger mechanism for analyzing and planning peacekeeping operations.

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13. ABSTRACT ***(Maximum 200 words)***

The goal of this project was to demonstrate the utility of distributed simulation for an area of active research in IDA's Strategy, Forces and Resources Division (SF&RD). For the purpose of this project, distributed simulation is synonymous with the Simulation Network (SIMNET), or its more current name, Distributed Interactive Simulation (DIS). After surveying SF&RD activities, the study team focused on research into the use of advanced sensors and information processing systems to support peacekeeping missions, an ongoing task for which SIMNET/DIS seemed well suited. The team conducted 18 trials to determine SIMNET's applicability as a tool for comparing the utility of different types of sensors, sensor deployment strategies, and strategies for deploying peacekeeping and security teams. The tests were not conducted under tightly controlled conditions, nor were they executed in accordance with a carefully designed test plan. The intent was not to draw inferences, but to explore SIMNET's utility in analyses of peacekeeping issues by running excursions under widely varying conditions.

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